IJSPT

ORIGINAL RESEARCH

COMPARISON OF SCAPULAR MUSCLE ACTIVATIONS DURING THREE OVERHEAD THROWING EXERCISES

Lisa Henning, MEd[1]
Hillary Plummer, PhD, ATC, LAT, CES[2]
Gretchen D. Oliver, PhD, FACSM, ATC, LAT, CES[1]

ABSTRACT

Background: With shoulder pain and injury on the rise in overhead athletes, clinicians are often examining preventative exercises to address functional abnormalities. Because shoulder impingement is prevalent in overhead athletes, much focus is on scapular stability and the function of the stabilizing force couple of the upper and lower trapezius and serratus anterior.

Hypothesis/Purpose: The purpose of this study was to examine scapular muscle activation during a series of throws and holds (throwing without releasing) with two different ball weights (7oz and 12oz). It was hypothesized that the holds exercises would elicit greater activation of the scapular musculature than the throw, irrespective of ball weight.

Study Design: Case control laboratory study

Methods: Twenty-two NCAA Division I, right hand dominant, softball players (19.91 + 1.04 years; 169.24 + 7.36 cm; 72.09 + 10.61 kg) volunteered to participate. Surface EMG was utilized to measure muscle activity in the upper, middle and lower trapezius and serratus anterior muscles during three different throwing activities.

Results: MANOVA results revealed no significant differences in muscle activity between throwing conditions, $F_{(16,82)} = 1.02$, $p = 0.446$, Wilks' $\Lambda = 0.696$, Cohen's d = 0.44 (7oz holds), 0.24 (12oz holds), power = 0.625.

Conclusion/Clinical Relevance: The results may provide some clinical insight in advocating the use of holds with different ball weights. The holds throw may be an effective step in shoulder strengthening that can more closely mimic the functional movement of throwing without the element of ball release.

Levels of Evidence: Level 3

Keywords: Baseball, injury, kinetic chain, rehabilitation, softball, upper extremity

[1] Sports Medicine and Movement Laboratory, Auburn University, School of Kinesiology. Auburn AL
[2] Division of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA, USA

CORRESPONDING AUTHOR
Gretchen D. Oliver
301 Wire Rd
Auburn University
Auburn, AL 36849
859-200-4035
E-mail: goliver@auburn.edu

INTRODUCTION

Shoulder pain and scapulohumeral dysfunction are common among overhead throwing athletes. Shanley et al[1] reported that the shoulder was the most frequently injured joint in high school softball and baseball players. Additionally, it has been reported that shoulder impingement is the most common cause of shoulder pain in overhead athletes.[2] Many authors have suggested that scapular movement abnormalities are linked to inefficient strength and stability of the scapular stabilizing muscles and thus contribute to shoulder injury.[3-7] As it is commonly known that the scapula plays an essential role in shoulder complex function,[8,9] the stability of the scapula through muscular balance is fundamental. It has been generally accepted that the force couple of the serratus anterior (SA) and trapezius musculature acts to dynamically stabilize the scapula.[8,9] When examining individuals with shoulder impingement, most have described greater activation of the upper trapezius (UT) combined with decreased activation of the lower trapezius (LT) and SA.[3,4,10,11] Additionally, altered activation has been reported as a contributor to diminished scapular posterior tilt and upward rotation, which are needed to maximize the amount of subacromial space for the rotator cuff tendons to pass through.[12] Therefore, due to the prevalence of shoulder injuries in overhead throwing athletes, there is a need to identify potential risk factors and also develop rehabilitation and strength training protocols that address scapular stability.

Traditionally, exercises targeting the scapular musculature have been limited to single planes of motion with the patient positioned prone, side lying or supine on a table;[12-16] though recently, shoulder exercises aiming to incorporate the entire kinetic chain are becoming more common.[17] The emphasis on the kinetic chain allows for the implementation of dynamic movement patterns throughout the rehabilitation process. These types of exercises are preferred by some, as proper kinetic chain sequencing of each interdependent body segment is needed to optimize the function of the most distal joint in the chain.[18] It has been reported that restoration of the dynamic scapular stabilizing musculature requires proper kinetic chain function.[17,19]Alterations at any other segment of the chain can affect the shoulder and dysfunction at the shoulder can impact the other segments of the chain as well.[18] Therefore, by implementing exercises that utilize the entire kinetic chain during training or rehabilitation, clinicians may be able to improve dysfunction at multiple segments, in addition to the shoulder, and better prepare the athlete to return to play.

One approach that throwers commonly use in the clinical setting is performing a throwing motion without releasing the ball. Though this exercise of throwing holds has been utilized commonly in overhead athletes and has been recognized by athletes, coaches, and sports medicine clinicians, no researchers to date have validated this type of holds exercise. The use of a holds throwing exercise may be a suitable exercise for improving strength throughout the entire kinetic chain before returning to full throwing activity. Although holds exercises are used clinically, their ability to activate the scapular muscles has not been investigated. Thus, in attempt to analyze the scapular musculature, the purpose of this study was to examine scapular muscle activation during a series of throws and holds (throwing without releasing) with two different ball weights (7oz and 12oz). It was hypothesized that the holds exercises would elicit greater activation of the scapular musculature than the throw, irrespective of ball weight.

METHODS

Study Design

The objective of this study was to determine activation of selected scapular muscles during three throwing activities; independent variables: typical overhead throw with 7oz ball + release (7oz throw), an overhead throw without releasing a 7oz ball (7oz holds exercise), and an overhead throw without releasing a 12oz ball (12oz holds exercise). During these throwing activities muscle activity was recorded using surface EMG on the following muscles of the throwing limb; dependent variables: UT, middle trapezius (MT), LT, SA. Descriptive statistics (mean ± standard deviation) were used to determine muscle activations by calculating normalized surface electromyographic (sEMG) data as a percent of the participant's maximum voluntary isometric contraction (%MVIC).

Participants

Twenty-two NCAA Division I softball players volunteered to participate. Demographics are listed in Table

1. Participant criterion for selection was freedom from upper extremity injury within the past six months. Additionally it should be noted that none of the participants reported any pain or stiffness in their upper or lower extremity following extensive throwing sessions within the previous six months. Additionally, no participants reported a history of upper extremity surgery. The Institutional Review Board of Auburn University approved all testing protocols. Prior to data collection, all testing procedures were explained to each participant and informed consent was obtained. All participants were tested during the off-season (four to six weeks following last competitive game) and had not thrown the day of testing.

Table 1. *Participant demographics*

Age (years)	Height (cm)	Mass (kg)
19.91 ± 1.04	169.24 ± 7.36	72.09 ± 10.61

Procedures

Throwing arm LT, MT, UT and SA muscle bellies were identified through palpation using previously described placements by Noraxon (Noraxon USA, INC, Scottsdale, Arizona).[20] The identified locations were then shaved, abraded, and cleaned using standard medical alcohol swabs for electrode placement. The same investigator performed all surface preparation as well as electrode placement. Subsequent to surface preparation, adhesive BIO Protech bipolar, 4cm Ag/AgCl diameter disk shaped, surface electrodes (Bio Protech Inc., Tustin, California) were attached over the muscle bellies and positioned parallel to muscle fibers using previously published standardized methods.[21-23] The selected inter-electrode distance was 25mm.[24]

Electromyographic data were collected via a Noraxon Myopac 1400L 8-channel amplifier (Noraxon USA, INC, Scottsdale, Arizona). Surface EMG data were visually monitored during the collection of data and sampled at a rate of 1000 Hz with an overall gain of 500. The raw signals were band-pass filtered with the low pass filter set to 80 Hz and the high pass filter set to 250 Hz. The common mode rejection ratio was set to >100 dB. The signal was full wave rectified and smoothed prior to analysis.

Following the application of surface electrodes, manual muscle testing (MMT) techniques as described by Kendall et al[25] were conducted to determine the maximum voluntary isometric contraction to which all EMG data would be normalized. MMTs were performed as follows: (1) SA: Participant was lying supine with the humerus in 90° of flexion and neutral rotation with the fingers flexed into a fist. The investigator applied a downward force towards the participant's forearm and humerus. (2) UT: Participant sat upright with the scapula elevated and neck laterally flexed to the contralateral side. The investigator applied pressure to the shoulder girdle in the direction of depression. (3) MT: The participant was lying prone with the shoulder in 90° of abduction with the thumb pointed upward. The investigator applied pressure against the forearm in a downward direction toward the table. (4) LT: The participant was lying prone with the arm placed diagonally overhead in line with the lower fibers of the trapezius and the thumb pointed upward.[25,26] The investigator applied pressure against the forearm in a downward direction toward the table. Two muscular contractions, lasting five seconds, were performed for each muscle and the first and last seconds were removed to obtain steady state results.[21] The data for the two contractions were averaged and a rest period of 30 seconds was allotted between each contraction.

Following establishment of the MVIC, participants were instructed on the protocol consisting of three conditions: (1) 7oz throw, (2) 7oz holds, and (3) 12oz holds. The throwing condition consisted of performing a maximum effort overhand throw on a straight-line trajectory preceded by a "crow hop". A crow hop is a lower extremity movement sequence that utilizes a skip and a hop prior to the throw being made.[27] The holds exercises consisted of mimicking the same maximum effort overhand throw, however, participants were instructed to not release the ball. Each condition was performed three times in a randomized order for testing. After instruction, participants were given an unlimited time to perform their own specified pre-competition warm-up routine. While participants were allowed to perform their own warm-up routine, all of their selected warm-ups included both static and dynamic exercises. A standardized warm-up protocol was not implemented because of the variability in how each participant preferred to warm-up prior to throwing. The average warm-up time was ten minutes. Once participants deemed themselves warm and ready for maximum effort throwing, they proceeded to perform the protocol described above. The muscular activity measured during the throwing motion was expressed as a %MVIC for all conditions and was examined as a single phase from maximum shoulder external rotation (Figure 1) to end of follow through (once the throwing hand crossed the midline of the body and came to a stop) (Figure 2). A single phase was chosen for the analysis since the objective was to quantify the overall average muscle activation throughout the throwing motion versus throughout multiple phases of the movement.[28-30] For comparison purposes, low muscle activity was considered to be between 0-20% MVIC while moderate activity was 21-40%, high muscle activity was 41-60%, and very high activity was >60%.[31,32]

Figure 1. *Maximum shoulder external rotation.*

Figure 2. *End of follow through.*

Statistical Analysis

Surface EMG data from each muscle were normalized and expressed as a percent contribution of the MVIC. Statistical analyses were performed using IBM SPSS Statistics 22 (Armonk, New York, USA). Descriptive data were expressed as means and standard deviations. Effect size and statistical power were also calculated. A 2 (holds, release) x 3 (holds 7oz, holds 12oz, throw 7oz) x 4 (muscles) multivariate analysis of variance (MANOVA) was conducted to evaluate the differences between the different throwing conditions and activity of the UT, LT, MT, and SA.

RESULTS

Descriptive data for the UT, LT, MT, and SA are presented in Table 2. Activation for the LT increased from moderate to high activation (approximately 39%MVIC in the 7oz throw to 41%MVIC in the 7oz hold, and 43%MVIC in the 12oz hold); MT increased from moderate to high activation (approximately 31%MVIC in the 7oz throw to 60% in the 7z hold, and 41% in the 12oz hold); SA was very high, and increased from approximately 74% in the 7oz throw to 83% in the 7oz hold, and 82% in the 12oz hold; and UT activation was moderate to high, increasing from approximately 36% in the 7oz throw to 39% in the 7oz hold, and 45% in the 12oz hold. As reported, a general trend toward increase in activation was observed in both holds exercises when compared to the throw for all four muscles, however the overall results were not statistically significant. MANOVA results revealed no significant differences in muscle activity between throwing conditions, $F_{(16,82)} = 1.02$, $p = 0.446$, Wilks' $\Lambda = 0.696$, Cohen's $d = 0.44$ (7oz holds), 0.24 (12oz holds), power = 0.625.

DISCUSSION

Shoulder impingement is one of the most common causes of shoulder pain in overhead athletes[2] and it

Table 2. *Descriptive statistics of muscle activations expressed as a %MVIC*

	7oz Throw	7oz Hold	12oz Hold	Significance
LT	39.26 ± 5.93	41.30 ± 6.78	43.74 ± 5.33	0.87
MT	31.71 ± 7.07	60.39 ± 8.09	41.30 ± 6.36	0.03*
SA	74.35 ± 7.04	83.40 ± 8.06	82.75 ± 6.34	0.61
UT	36.08 ± 5.59	39.80 ± 6.40	44.93 ± 5.03	0.50

* Although there was a significant interaction in the post-hoc test for MT, there was no significant interaction in the overall statistical test.

is often the result of functional abnormalities such as scapular muscle imbalances.[3,33,34] The scapular muscle imbalance frequently observed in individuals with shoulder pain and impingement shows increased UT and decreased LT and SA muscle activation.[3,10,11] Therefore, sports medicine professionals will often target these muscles when addressing either rehabilitation or injury prevention programs for overhead athletes in effort to reduce pain and improve shoulder function. Often in the clinical setting, injured baseball and softball players will perform holds exercises prior to the initiation of an interval throwing protocol in attempt to initiate scapular muscle activation prior to throwing.

The results of this study revealed that scapular muscle activations were similar between the three conditions in healthy NCAA Division I softball players. The lack of significant differences in muscle activation may help to support the use of the holds exercise in training and rehabilitation programs. The holds exercise produces similar muscle activations to that of a throw, but may not result in the same stresses being placed on the upper extremity that have been reported in the literature to occur at ball release and maximum internal rotation during a throw.[35] By quantifying scapular muscle activation data for these exercises, future research may progress to better understand the kinetic differences between a throw and the holds exercises. It is known that the overhead throwing motion requires optimal function of the entire kinetic chain to transfer energy in addition to a great deal of neuromuscular efficiency.[36] As a thrower advances through the training or rehabilitation process, they must progress from basic strengthening of the scapular musculature and surrounding shoulder musculature to more functional movements that mimic the throwing motion. As researchers and clinicians have gained a greater understanding of the importance of rehabilitating the kinetic chain as a whole, there has been a shift toward exercises that incorporate full body movement to retrain the body's ability to transfer kinetic energy in an effective manner.

While no statistically significant differences between the three conditions were observed in this study, the results give insight into the use of potential holds exercises that target the scapular musculature for overhead throwing athletes. The examination of the level of activity for the LT, MT, SA, and UT is still pertinent. The results of this study revealed moderate (21%-40%), high (41%-60%), and very high (>61%) activations of the LT, MT, SA, and UT during all three of the examined conditions. It is speculated that these activations were a result of the LT, MT, SA, and UT functioning to control movement of the scapula. The values observed in the current study are similar to activations of the scapular musculature observed in previous shoulder rehabilitation studies examining scapular muscle activation during individual joint exercise and rehabilitation movements.[37-39] Only one current study has examined lower trapezius, upper trapezius, and serratus anterior muscle activation during baseball pitching.[28] In the abovementioned study, low activation was observed for the LT throughout the entire pitching motion and the UT and SA exhibited low activation between foot contact and maximum shoulder external rotation. Moderate and high activations of the SA and UT were observed during the acceleration and follow through phases of the pitch, respectively. By having similar levels of muscle activations observed in previously reported data during rehabilitation exercises, the holds exercises may be an alternative exercise that can be performed to best simulate the muscular demands of throwing when a player may not be medically cleared to throw. Therefore, the current results may further support the idea of a holds throw being an effective exercise that can more closely mimic the functional demands of throwing, when compared to traditional rehabilitation exercises, without the added risk of high forces about the shoulder that are produced at ball release.

Moderate activations were seen in LT and UT in the regulation weight ball holds condition and in LT, MT, and UT in the weighted ball holds exercises. It was hypothesized that greater scapular musculature activation would be observed in the weighted ball holds exercises compared to the regulation weight holds but significantly greater activation was not observed. Activation of the MT did however reach a moderate level in the 12oz holds exercise that was not observed in the 7oz holds exercise. It is speculated that the 12oz hold exercise may be more advantageous than traditional single-plane exercises because it requires the athlete to grip the ball throughout the entire holds throwing exercises.

While valuable data on sEMG data during throwing and a series of holds exercises were obtained it is important to note that some limitations do exist. The use of sEMG during a dynamic movement allows for the possibility of movement artifact due to movement of the muscle under the skin and thus the electrodes. Second, the current study examined healthy participants with no known upper extremity injury and the muscle activations observed in this study might not be indicative of those seen in athletes with injured shoulders. Another limitation of the study is that the participants were not evaluated for scapular dyskinesis, which may be present in a healthy and uninjured population. This was an exploratory descriptive study using healthy participants, and there is a need in the future to examine participants with scapular dyskinesis to see if the results would be similar. Future research should examine the use of a holds throwing exercises in affected participants who are transitioning from an upper extremity rehabilitation not to an interval long toss program and examine the effects of using balls of various weights for rehabilitative purposes. Additional kinetic analyses comparing throwing to holds throwing are needed to help determine if the forces about the upper extremity are impacted when not releasing the ball.

CONCLUSIONS

The results of the current study showed high activation of the LT (41.3%MVIC) and moderate activation for UT (39.8%MVIC) in the regulation weighted holds exercises and in LT (43.74%MVIC), MT (41.30%MVIC), and UT (44.93%MVIC) in the weighted ball holds exercises. The holds exercises also produced similar scapular muscle activations compared to those seen when throwing a softball. While definitive conclusions cannot be drawn, it is speculated that the holds exercises may be an alternative method for gaining similar muscle activation patterns compared to an actual throw. Thus, the use of a throwing holds exercise utilizes a sport specific movement that may bridge the gap between traditional scapular exercises and a subsequent return to throwing program.

REFERENCES

1. Shanley E, Rauh MJ, Michener LA, Ellebecker TS. Incidence of injuries in high school softball and baseball players. *J Athl Train.* 2011;46(6):648-654.
2. Tibone J, Shaffer B. Shoulder pain: When is it impingement? *J Musculo Med.* 1995;12(4):65-77.
3. Cools AM. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. *Br J Sports Med.* 2004;38(1):64-68.
4. Cools AM, Witvrouw EE, Mahieu NN, Danneels LA. Isokinetic scapular muscle performance in overhead athletes with and without impingement symptoms. *J Athl Train.* 2005;402(2):104-110.
5. Glousman R, Jobe F, Tibone J, Moynes D, Antonelli D, Perry J. Dynamic electromyographic analysis of the throwing shoulder with glenohumeral instability. *J. Bone Joint Surg.* 1988;70-A(2):220-226.
6. Glousman R. Electromyographic analysis and its role in the athletic shoulder. *Clin Orthop Relat Res.* 1993;288:27-34.
7. Scovazzo MBA, Pink M, Jobe F, Kerrigan J, . The painful shoulder during freestyle swimming: An electromyographic and cinematographic analysis of twelve muscles. *Am J Sports Med.* 1991;19:577-582.
8. Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med.* 1998;26(2):325-337.
9. Mottram SL. Dynamic stability of the scapula. *Man Ther.* 1997;2(3):123-131.
10. Cools AM, Witvrouw EE, Declercq GA, Danneels LA, Cambier DC. Scapular muscle recruitment patterns: trapezius muscle latency with and without impingement symptoms. *Am J Sports Med.* 2003;31(4):542-549.
11. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther.* 2000;80(3):276-291.
12. Cools AM, Dewitte V, Lanszweert F, et al. Rehabilitation of scapular muscle balance: which exercises to prescribe? *Am J Sports Med.* 2007;35(10):1744-1751.
13. Cools AM, Witvrouw EE, Declercq GA, Danneels LA, Cambier DC. Scapular muscle recruitment patterns: Trapezius muscle latency with and without impingement symptoms. *Am J Sports Med.* 2003;31(4):542-549.
14. Reinold MM, Gill TJ. Current concepts in the evaluation and treatment of the shoulder in overhead-throwing athletes, part 1: physical characteristics and clinical examination. *Sports Health.* 2010;2(1):39-50.
15. Kibler WB, Sciascia AD, Uhl TL, Tambay N, Cunningham T. Electromyographic analysis of specific exercises for scapular control in early phases

of shoulder rehabilitation. *Am J Sports Med.* 2008;36(9):1789-1798.

16. Tucker S, Armstrong CW, Swartz EE, Campbell B, Rankin JM. An electromyographic analysis of the cuff link rehabilitation device. *J Sport Rehab.* 2005;14:124-136.
17. McMullen J, Uhl TL. A kinetic chain approach for shoulder rehabilitation. *J Athl Train.* 2000;35(3):329-337.
18. Kibler WB, McMullen J, Uhl TL. Shoulder rehab strategies, guidelines, and practice. *Oper Tech Sports Med.* 2000;8(4):258-267.
19. Sciascia A, Cromwell R. Kinetic chain rehabilitation: a theoretical framework. *Rehabil Res Pract.* 2012;2012:853037.
20. Konrad P. The ABC of EMG: A practical introducation of kinesiological electromyography. 2006:61. http://www.noraxon.com/wp-content/uploads/2014/12/ABC-EMG-ISBN.pdf. Accessed January 03, 2016.
21. Oliver GD, Stone AJ, Plummer H. Electromyographic examination of selected muscle activation during isometric core exercises. *Clin J Sport Med.* 2010;20(6):452-457.
22. Cram JR, Holtz J. Electrode Placement. *Introduction to Surface Electromyography*. Gaithersburg, MD: Aspen Publishers; 1998.
23. Basmajian JV, de Luca CJ. *Muscles alive: Their functions revealed by electromyography.* 5th ed. Baltimore: Williams & Wilkins; 1985.
24. Hintermeister RA, Lange GW, Schultheis JM, Bey MJ, Hawkins RJ. Electromyographic activity and applied load during shoulder rehabilitation exercises using elastic resistance. *Am J Sports Med.* 1998;26:210-220.
25. Kendall F, McCreary EK, Provance PG, Rodgers MM, Romani W. *Muscles: Testing and function.* 4 ed. Baltimore, MD: Williams & Wilkins; 1993.
26. Ekstrom R, Soderberg G, Donatelli R. Normalization procedures using maximum voluntary isometric contraction for the serratus anterior and trapezius muscles during surface EMG analysis. *J Electromyogr Kinesiol.* 2005;15(4):418-428.
27. Reinold MM, Wilk K, Reed J, Crenshaw K, Andrews J. Interval sport programs: Guidelines for basebll, tennis, and golf. *J Orthop Sports Phys Ther.* 2002;32(6):293-298.
28. Oliver GD, Weimar WH, Plummer HA. Gluteus medius and scapula muscle activation in youth baseball pitchers. *J Strength Cond Res.* 2015;29(6):1494-1499.
29. Oliver GD, Keeley DW. Gluteal muscle group activation and its relationship with pelvis and torso kinematics in high-school baseball pitchers. *J Strength Cond Res.* 2010;24(11):3015-3022.
30. Plummer H, Oliver GD. The Relationship Between Gluteal Muscle Activation and Throwing Kinematics in Baseball and Softball Catchers. *J Strength Cond Res.* 2013.
31. DiGiovine NM, Jobe FW, Pink M, Perry J. An electromyographic analysis of the upper extremity in pitching. *J Shoulder Elbow Surg.* 1992;1(1):15-25.
32. Escamilla RF, Andrews JR. Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports. *Sports Med.* 2009;39(7):569-590.
33. Kibler WB, Kuhn JE, Wilk K, et al. The disabled throwing shoulder: spectrum of pathology—10-year update. *Arthroscopy.* 2013;29(1):141-161 e126.
34. Kibler WB, McMullen J, Uhl T. Shoulder rehabilitation strategies, guidelines, and practice. *Oper Tech Sports Med.* 2012;20(1):103-112.
35. Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med.* 1995;23(2):233-239.
36. Provencher MT, Makani A, McNeil JW, Pomerantz ML, Golijanin P, Gross D. The role of the scapula in throwing disorders. *Sports Med. Arthrosc.* 2014;22(2):80-87.
37. Decker MJ, Hintermeister RA, Faber KJ, Hawkins RJ. Serratus anterior muscle activity during selected rehabilitation exercises. *Am J Sports Med.* 1999;27(6):784-791.
38. Myers JB, Pasquale MR, Laudner KG, Sell TC, Bradley JP, Lephart SM. On-the-field resistance-tubing exercises for throwers: An electromyographic analysis. *J Athl Train.* 2005;40(1):15-22.
39. McCabe R, Orishimo K, McHugh M, Nicholas S. Surface electromyographic analysis of the lower trapezius muscle during exercises performed belowe ninety degrees of shoulder elevation in healthy subjects. *N Am J Sports Phys Ther.* 2007;2(1):34-43.